ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 5 September 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2020; 20(5): 16371-16385 https://doi.org/10.18697/ajfand.93.19170

PHYSIOCHEMICAL PROPERTIES AND NUTRITIONAL PROFILE OF MEDITERRANEAN OAK ACORN

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Volume 20 No. 5
September 2020
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ABSTRACT

Oaks cover a vast area of Jordanian forests, and their fruit (named acorns) have good nutritional value. In this study, we investigated the physical, chemical, and nutritional characteristics of the acorns produced by three Jordanian oak species, *Quercus aegilops* (QA), *Quercus infectoria* (QI), and *Quercus calliprinus* (QC). The physicochemical (acorn length, weight; cupule weight, coat weight, cotyledon weight, coat weight percent, cotyledon weight percent and acorn volume) and nutritional quality (protein, fat, fiber, ash, carbohydrate, amino acid, fatty acid and mineral compostions) of the acorns from the three oak species were determined using standard procedures. The acorn of QA showed significantly greater values compared to QC for all physical characteristics assessed while QC exhibited the lowest values; QI presented intermediate values.The chemical composition of the three species showed that fat content varied from 8.18% to 8.99% and the crude fiber and the total carbohydrate content ranged from 3.27% to 3.86% and 76.20% to 81.43%, respectivelyAccording to obtained results, oak acorn can be considered a significant source of protein (9.54% for QC to 10.9% for QA). Oak acorn contained 18 known amino acids (AAs); with total essential amino acids (TEAA) levels in these oak species as 2307.9, 1699.1, and 2262.8 mg/100 g dry weight, respectively. The most abundant essential amino acid found varied between species: in QA it was leucine (446 mg/100 g dry weight), in QC it was arginine (526 mg/100 g dry weight), and in QI it was phenylalanine (395 mg/100 g dry weight). The ratio of TEAA to total amino acids (TAA) was 0.90: 0.50 and 0.79 for QA, QC and QI, respectively, which indicates that QA is the best species in terms of essential amino acid (EAA) proportion. The EAA scores showed that (phenylalanine + tyrosine) and (methionine + cysteine) were the most abundant AAs in oak acorns, while lysine and leucine were the most limited. The ratio of unsaturated fatty acids to saturated fatty acids in the acorn oil ranged from 3.45:1.00 to 3.93:1.00. Therefore, oak acorn oil may be considered healthy for a human diet. The most abundant minerals in decreasing order were K, P, Ca, Cl, S, Fe, and Mn. These results demonstrate that oak acorns from Jordan have great potential to be included in human feeding.

Key words: Amino acids, Fatty acids, Nutritional value, Oak acorn, *Quercus* L.

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INTRODUCTION

Oaks belong to *Quercus* genus, which includes more than 300 species in the temperate ecosystem. Many species of *Quercus* are characteristic of the Mediterranean region [1]. Jordan, as part of the Eastern Mediterranean region, constitutes one of the richest ecosystems, inhabited by plant species originating from many different regions such as Western Europe, Central Asia, and Eastern Africa. Oak trees are deciduous or evergreen species abundantly found in the Jordanian forests and may have vast potential for economic exploitation.

The number of oak trees in Jordan could exceed that of olive trees [2]; based on an estimated forest area of 50,000 ha and an estimated density of 300 trees per ha, there may be more than 15 million oak trees [3]. Knowing that the estimated annual productivity of each oak tree averages 10 kg [4], the estimated oak acorn production may reach about 150,000 metric tons. Rosenberg [5] reported that the Mediterranean Basin has annual production rates ranging from 120 to 700 kg per ha.

There are several oak species known to exist in Jordan. *Quercus aegilops* has recently been designated as the national tree of Jordan due to its economic and ecological significance and also based on utilization criteria. The estimated number of *Quercus aegilops* species tree in Jordan is about 1.5 million [6].

Historically, the *Quercus* fruit (acorn) was consumed by the local population and used as a traditional local feed resource. Besides, *Quercus* fruits, galls, resin, and leaves have a long tradition in folk medicine [7]. Acorns have been used as food by Homo sapiens for thousands of years [8]. Despite the relatively large areas and number of oak trees and their diversity in Jordan, scientific studies describing the nutritional value of the different types of fruits of these trees are scarce. Therefore, we conducted this study to conduct the physical chemical and nutritional analysis of three types that are prevalent in Jordan to be available to those interested.

MATERIALS AND METHODS

Samples collection and preparation

A sample of 4-5 kg of fully mature and healthy acorn fruits from three species included in the study: Quercus aegilops (QA), Quercus infectoria (QI) and Quercus calliprinus (QC), were manually and randomly collected from 6 trees at close ages distributed in Northern, Middle, and Southern regions of Jordan during November 2017-2018. The three species were identified by specialists at the Directorate of Forestry, Jordanian Ministry of Agriculture according to Post [9].

Physical analysis

An average of three replicated acorn samples of each oak species was used to determine the length (cm), weight (g), and fruit volume (mL). As the whole acorn consists of three parts, cupule, coat, and cotyledons, acorns were manually partitioned to measure the weight of each of these parts separately.

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Proximate analysis

Air-dried mature acorn samples of each *Quercus* species were dehulled, and the kernels (dicotyledonous) were ground into meal and homogenized with a pestle and mortar, then stored in plastic containers at −18 °C until analysis.

Crude protein (Kjeldahl, N x 6.25) (Method 981.10 - AOAC, 1990), fat (Soxhlet, solvent extraction) (Method 932.06 - AOAC, 1990), crude fiber (Method 985.29- AOAC, 1990), ash (Method 923.03 - AOAC, 1990) and moisture contents (Method 925.09- AOAC, 1990) were determined according to the standard methods [10].

Amino acid analysis

The amino acids profiles of the acorns belonging to the different oak species were obtained using an automatic amino acid analyzer model S 433 (Sykam GmbH, Eresing, Germany). Briefly, 10 mL of HCl (6 N) was added to each 0.1 g sample in a test tube. The sample was hydrolyzed at 110°C for 20 h under continuous stirring and then allowed to cool to room temperature. All hydrolysate was quantitatively transferred with distilled water, filtered through a Whatman filter paper No. 1 to remove sediments, and then evaporated to dryness under vacuum at 65°C. The residue obtained was dissolved in 1 mL of buffer (pH 2.2), and 100 µL of this solution was injected (using an autosampler at 12°C) into the amino acid analyzer to estimate the amino acids profiles. Tryptophan content was then determined using the basic hydrolysis method [11]. Oak acorn powder (0.1 g) was treated with 10 mL of sodium hydroxide (4.2 M) and hydrolyzed at 110 °C for 20 h. After cooling, the pH was adjusted to 4.5. A programmable column-oven with temperatures ranging from 37°C to 74 °C was set as standard on the analyzer; a special reagent pump ("ninhydrin pump") was used to deliver ninhydrin with a flow rate of 0.25 mL/min, and the buffer pump was adjusted to a flow rate of 0.45 mL/min. The inert gas (N_2) was supplied with a pressure of 0.5 bar to prevent buffer/reagent oxidation and contamination. A dual-channel photometer for amino acid detection set at λ = 440 nm for proline, OH-proline, and tryptophan, and at λ= 570 for all other amino acids was used [10].

The amino acid score (AAS) was determined to evaluate the proportion of essential amino acids (EAA) in oak acorns. This was calculated as the ratio of each EAA content to FAO/WHO/UNU amino acid recommendations [11], as follows:

$$\text{Amino acid score (\%)} = \frac{\text{mg of essential amino acids in 1 g of the test protein}}{\text{mg of essential amino acid in 1 g of the reference protein}} \times 100$$

Lipid extraction

About 100 g of finely ground oak acorn meal was immersed in 500 mL of hexane in a dark flask and stirred using a magnetic stirrer for 7 h at room temperature. The mixture was centrifuged for 10 min at 2000 rpm, and the supernatant was filtered through a Whatman filter paper No. 2. The extraction process was repeated once. The collected solvent was removed using a rotary evaporator at 40°C. The fatty fraction obtained was kept in a closed bottle (50 mL) until analysis.

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Fatty acid composition

Fatty acid methyl esters (FAMEs) from oak acorn oil were prepared according to the Commission Regulation (EEC) No. 2568, established in 1991. Briefly, 50 mg of lipid extract was weighed, dissolved in 2 mL hexane (GC grade) and mixed by vortexing for 1 min. A 200 µL-aliquot of potassium hydroxide (2 M) prepared in anhydrous methanol was added and mixed for 30 s until the solution became clear and then, 200 µL of acetic acid was added and mixed for 30 s. The prepared methyl esters were analyzed using a capillary GLC column (Restek, Rtx-225, USA, cross bond 50%-cyanopropylmethyl 50%-phenylmethyl polysiloxane, 60 m, 0.25 mm ID, 0.25 µm d_f) immediately after esterification, by injecting 1 µL samples of the hexane layer through the injection port of the GLC (model GC-2010, Shimadzu. Inc., Kyoto, Japan). The column oven temperature was 165°C for 10 min; subsequently, it was increased to 185 °C (at a rate of 1°C/min) and then kept at 185°C for 1 min; in a second step, the temperature was increased to 220°C (at a rate of 3 °C/min) and kept at 220°C for 20 min. The injector temperature was 240°C, the flame ionization detector temperature was 260°C, the flow rate of the carrier gas (helium) 0.8 mL/min, and the split ratio used was 80:1. The fatty acids methyl esters (FAMEs) were identified using fatty acid standards (12-24 carbon atoms).

Mineral analysis

The mineral contents of acorn cotyledons in the three oak species were determined according to the procedure outlined by the Association of Official Analytical Chemists (1990) using an atomic absorption spectrophotometer.

Mature acorn cotyledons (3–4 per oak species) were dried at 90°C (Memmert 854, Schwabach, West Germany) on an aluminum foil for 3 days and ground with mortar and pestle. Subsequently, 300 mg samples (dry weight) were wet-digested on a hot-plate using HNO_3 (65 %) for 5 days. For K, Zn, Fe, and Cu determination, the cleared solutions were filtered through ashless filter paper and then diluted with deionized water. Mineral analyses were carried out in an atomic absorption spectrophotometer (Shimadzu AA-680, Japan) according to Bayçu and Önal [12]. Total concentrations of K, Zn, and Cu were obtained by measuring, respectively, at 766.5, 213.9, and 324.8 nm (emission mode), Fe concentrations were estimated based on readings at 248.3 (absorption mode). All reagents were of analytical grade, and all analyses were conducted in triplicate. Results are expressed in µg/g (dry weight basis).

Statistical analysis

Statistical analysis was conducted of physical and chemical data using analysis of variance (two-way ANOVA) with SAS Version 8.2 software package [13]. Means were compared using the least significant difference (LSD) test at $p \leq 0.05$. All experiments were carried out in triplicate; some results are expressed as means ±standard deviations (SD).

RESULTS AND DISCUSSION

Physical and Chemical properties of oak acorn

The physicochemical properties of the acorns of *Quercus aegilops* (QA), *Quercus calliprinus* (QC), and *Quercus infectoria* (QI) are presented in Table 1. *Quercus aegilops*

(QA) showed significantly higher values in all physical characteristics assessed while QC exhibited the lowest values ($p \leq 0.05$); QI presented intermediate values. The acorn length in the three oak species analyzed was higher than that reported for *Quercus suber* L. acorn (1.821 cm) [14].

The results obtained are similar to those mentioned by Amina *et al*. [15], who reported that the length of acorn nut (*Quercus ilex* L.) was 3.999 cm, and are also in agreement with those published by Rababah *et al*. [16], who reported that *Q. calliprinus* was found to produce smaller acorns. The relative cotyledon weight in QA, QC, and QI acorns (expressed as percent respect to the total acorn weight) was 73.43%, 75.65%, and 78.64%, respectively. These values are below that mentioned by Rakić *et al*. [17] for *Quercus robur* acorn (85.66 %). According to these authors, the physical characteristics of oak's fruit are important for several reasons, foremost because they affect the nut collecting procedure, the mechanical separation of the shell from the nut, the drying, and the crushing or milling.

While, the proximate analysis of QA, QC, and QI acorns were illustrated in Table 1 showed that the crude protein content for all *Quercus* species ranged from 9.54 % to 10.90 %, with QA showing the highest value. Vinha *et al*. [18] reported that protein was the second component in oak acorns, reaching maximal contents in *Q. suber* (9 g/100 g dry matter). Özcan [19] reported that the total protein content in twenty Turkish Quercus taxa ranged from 2.75 % to 8.44 %, which are lower values in some cultivars than those found in this study for Jordanian oak species, although the values were close to other varieties.

On the other hand, the highest crude fat content was also found in QA (7.8 %), while the lowest corresponded to QC, in line with data previously reported for the same species [20]. This result concludes that *Quercus* content of oil has no economic viability, but might have potential other purposes, such as pharmaceutical, industrial, in addition nutritional (20).

The ash contents ranged from1.47 to 1.77 as shown in Table 1. These values indicate that the three species we analyzed were similar to those reported by Amina *et al*. [15] and other researchers [21, 22]. Saffarzadeh *et al*. [23] reported that the ash content of *Quercus brantii* acorn was 1.5%.

The crude fiber and the total carbohydrate content (represented by the nitrogen-free extract, NFE) ranged from 3.27 % to 3.86 % and 76.20 % to 81.43 %, respectively. The QC was the species displaying the highest value for nitrogen-free extract (%), while the highest crude fiber level (%) was found in QI acorns, indicating that acorns represent a good source of starch and fiber. Likewise, Vinha *et al*. [18] reported that in all *Quercus* spp. studied, carbohydrates were the major component, with similar values for all species (86–89 g/100 g dry weight; in addition, Saffarzadeh *et al.* [23] reported that the nitrogen-free extract content of Quercus brantii acorn was 78.17 %.

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Amino acid composition of oak acorn

Table 2 shows acorn amino acid composition in QA, QC, and QI. Eighteen known amino acids were identified. The total essential amino acids (TEAA) levels in QA, QC, and QI were 2307.9, 1699.1, and 2262.8 mg/100 g dry weight, respectively. The most abundant essential amino acid found varied between species: in QA was leucine (446 mg/100 g dry weight), in QC was arginine (526 mg/100 g dry weight), and in QI was phenylalanine (395 mg/100 g dry weight). Özcan [19] indicated that different amino acid profiles reflect the specific characteristics of a protein; besides, the embryonic and extra embryonic seed tissues in different taxa are genetically controlled and therefore, being less affected by environmental conditions in the maturing period. Regarding the nutritive value, oak acorns may be considered a relatively rich source of some amino acids.

The highest level of total conditionally essential amino acids (TCEAA) was found in QI (1358 mg/100 g dry weight) and the lowest in QC (821 mg/100 g dry weight). However, QC displayed the highest content of total non-essential amino acids (TNEAA).

A considerable variability for individual amino acids concentrations was detected in these three oak species. However, when comparing the ratio of total essential amino acids to the rest of the amino acids (TEAA/(TNEAA+TCEAA), QA was found to be the species with the highest ratio (0.9), whereas the lowest ratio (0.5) was observed in QC, indicating that QA was the best species in terms of essential amino acids proportion in the acorn. This oak species is famous in Jordan and known as the national tree; their acorns taste sweet. It was reported that acorn protein is more nutritious than that of pecans [19]. Products from acorn can be prepared with other foods and could add useful amounts of amino acids to the diet. Therefore, due to lower levels of some essential amino acids, the acorn cannot be solely used to formulate an infant formula.

Table 3 shows the amino acid scores (%) of the acorns of QA, QC, and QI identified in Jordan. The amounts of all essential amino acids examined in oak acorn proteins were not sufficient, according to the Joint WHO/FAO/UNU Expert Consultation [11] reference values. Nevertheless, the amounts of (phenylalanine + tyrosine) and (methionine + cysteine) in the acorns of QA and QI presented adequate patterns, fitting the requirements of the above mentioned institutions. Pellett and Young [24] reported that the lowest score obtained for essential amino acids defines the most limiting amino acid. According to this concept, the limiting amino acids in the acorns analyzed were lysine for QA and QI (scores of 52.8 % and 39.2 %, respectively) and leucine for QC (score of 18.14 %). These results differ from those obtained by Özcan [19], who reported higher amounts of leucine, lysine, and valine than any other essential amino acid in *Quercus* taxa protein. These differences might be due to variety of oak species and environment conditions as mentioned by Özcan [19].

Fatty acid composition of oak acorn oil

The fatty acid composition of acorn oil from QA, QC, and QI is shown in Table 4. The highest total saturated fatty acid content was observed in QI (22.46 %), followed by QC and its content was 4.86 % less than the QI, while QA was 10.69% less than QI content. The highest unsaturated fatty acids content was recorded in QA (79.81 %), which was 1.5% more than QC and 2.88% more than QI. It was previously reported that MUFA

contents in the acorn of different *Quercus* species ranged from 53 % to 69 %, the PUFA contents from 15 % to 27 %, and saturated fatty acids levels from 16 % to 22 % [18]. The results of this study agree with the previous reported data Al-Rousan *et al*. [20] for the same species. On the other hand, the ratio of total unsaturated fatty acids to total saturated fatty acids was between 3.45:1 and -3.93:1; these elevated ratios may be due to the high contents in oleic acid and linoleic acid found in line with previous observations [20, 25]. In this sense, it was already reported that oleic and linoleic acids were the predominant fatty acids in the acorn of *Quercus* species [18, 26]. Therefore, for nutritional purposes, oak acorn oil might be healthy for the human diet due to its high content of MUFA [20, 25].

Mineral composition of oak acorn

The mineral composition of QA, QC, and QI acorns is shown in Table 5. The most abundant minerals in decreasing order were K, P, Ca, Cl, S, Fe, and Mn; however, there are significant differences ($p \leq 0.05$) between the three species in most of the mineral contents. The content of other minerals varied among the different oak species. Özcan and Bayçu [27] reported that variations in cation uptake selectivity occur between taxa from different ecological habitats, and elemental concentration in plant materials strongly depend on uptake genotypic characters, in addition to soil properties. All oak acorn species examined showed high K concentrations compared with other elements, especially QI. The results obtained tend to agree with those communicated by other researchers, who found that potassium was much more abundant in oak acorns than phosphorus [27, 28]. The potassium is an important element that affects of the intra- and extracellular osmotic pressure, the bioelectricity of cell membranes and the enzymatic degradation of carbohydrates, while phosphorus has attributes of maintaining the normal acid-base equilibrium in the body [28].

CONCLUSION

The current study revealed that the three types of Jordanian oak acorn species (Quercus aegilops, Q. calliprinos, and Q. infectoria) have a potential value for use in human food, especially as they contain significant contents of protein, fat, minerals and high content of carbohydrates. This indicates the possibility of using it in different food products, such as acorn chips, TV snacks, bread, biscuit, coffee, ice cream and other desserts and liqueurs. There are challenges for the forestry sector and the food industry related to the harvesting and processing of oak acorn. However, as a starting point, a full economic analysis of acorn harvesting and processing in Jordan is needed.

ACKNOWLEDGEMENTS

The authors acknowledge the funding support given by Al-Balqa Applied University/Jordan.

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Table 1: Physical properties and nutritional composition of acorns produced by three Quercus L. species

Physical properties[§]	*Q. aegilops*	*Q. calliprinus*	*Q. infectoria*	*p-value*
acorn length (cm)	4.21 ±0.97[a]	2.72±0.65[c]	3.34±0.76[b]	0.0002
acorn weight (g)	16.22±2.26[a]	5.34±1.21[c]	10.30±1.87[b]	0.0001
cupule weight (g)	5.45±1.40[a]	1.60±0.23[c]	2.60±0.67[b]	0.0001
coat weight (g)	4.31±1.04[a]	1.30±0.24[c]	2.20±0.48[b]	0.0001
cotyledon weight (g)	11.91±2.08[a]	4.04±1.33[c]	8.10±1.89[b]	0.0001
coat weight (%)	26.57±1.26[a]	24.35±1.29[b]	21.36±1.04[c]	0.0053
cotyledon weight (%)	73.43±0.81[c]	75.65±0.20[b]	78.64±1.12[a]	0.0006
acorn volume (mL)	9.4±2.47[a]	3.13±1.19[c]	6.32±1.55[b]	0.0001
Nutritional compositions [φ]				
Crude protein (%)	10.90 ±1.65[a]	9.54 ± 1.33[b]	9.75 ± 1.79[b]	0.0067
Crude fat (%)	7.80 ± 0.95[a]	3.99 ± 1.04[b]	7.18 ± 1.20[a]	0.0001
Crude fiber (%)	3.63 ± 1.02[ab]	3.27± 0.99[b]	3.86 ± 1.10[a]	0.0291
Ash (%)	1.47 ± 0.34[c]	1.77 ± 0.51[a]	1.66 ± 0.58[b]	0.0001
Nitrogen-free extract (NFE)(%)[¥]	76.20±0.52[c]	81.43±0.96[a]	77.55±0.78[b]	0.0001

[§]Values are mean ±standard deviation; $n = 3$

Means with different letters in the same row are significantly different at ($p \leq 0.05$) according to LSD test

[φ]All values are expressed on a dry weight basis

[¥]NFE - total carbohydrates: calculated by difference

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Table 2: Amino acid composition of acorns produced by three *Quercus* L. species[§]

	Q. aegilops	***Q. calliprinus***	***Q. infectoria***
Essential amino acids			
Isoleucine	196 (4.0)[¥]	186 (3.7)	339 (6.6)
Leucine	446 (9.0)	102 (2.03)	330 (6.6)
Lysine	259 (5.2)	176 (3.5)	172 (3.4)
Threonine	168.6 (3.4)	87 (1.7)	147 (2.9)
Valine	297 (6.0)	297 (5.9)	451 (8.8)
Arginine	335 (6.7)	526 (10.5)	169 (3.3)
Histidine	144 (2.9)	117 (2.3)	128 (2.5)
Phenylalanine	315 (6.3)	129 (2.6)	395 (7.7)
Methionine	136 (2.7)	69 (1.3)	122 (2.4)
Tryptophan	11.3 (2.3)	10.1 (0.2)	9.8 (0.19)
Total essential amino acids (TEAA)	2307.9 (48.5)	1699.1 (33.73)	2262.8 (44.39)
Conditionally essential amino acids			
Proline	260 (5.2)	504 (10.1)	635 (12.4)
Glycine	436 (8.8)	120 (2.4)	285 (5.6)
Cysteine	150 (3.0)	54 (1.1)	67 (1.3)
Tyrosine	326 (6.6)	143 (2.9)	371 (7.3)
Total conditionally essential amino acids (TCEAA)	1172 (23.6)	821(16.5)	1358 (26.6)
Non-essential amino acids			
Aspartic acid	27.3 (0.55)	54 (1.1)	35 (0.7)
Glutamic acid	543 (10.9)	1043 (20.8)	295 (5.8)
Serine	266.1 (5.4)	471 (9.4)	136 (2.7)
Alanine	555 (11.4)	993 (18.8)	1030 (20.1)
Total non-essential amino acids (TNEAA)	1391.4 (28.25)	2561 (50.1)	1496 (29.3)
Total amino acids (TAA)	4871.3	5081.1	5116.8
TEAA/TAA (%)	47.38	33.44	44.22
TCEAA/TAA (%)	24.06	16.16	26.54
TNEAA/TAA (%)	28.56	50.40	29.24
TEAA/(TNEAA+TCEAA) ratio	0.90	0.50	0.79

[§] Values are mean of amino acid (mg/100 g) dry weight
[¥]Numbers in parentheses represent relative percent

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Table 3: Amino acid scores of acorns produced by three *Quercus* L. species based on FAO/WHO/UNU (2007)

Essential amino acids (mg/g protein)	*Q. aegilops*	*Q. calliprinus*	*Q. infectoria*	FAO/WHO /UNU (2007) mg/g protein	*p-value*
Isoleucine	59.93^{c}	65.00^{b}	115.00^{a}	30	0.0001
Leucine	69.32^{a}	18.14^{c}	57.37^{b}	59	0.0001
Lysine	52.80^{a}	41.00^{b}	39.20^{c}	45	0.0001
Threonine	67.26^{a}	39.65^{c}	65.57^{b}	23	0.0001
Valine	69.87^{c}	79.82^{b}	118.61^{a}	39	0.0001
Histidine	88.07^{a}	81.73^{b}	87.53^{a}	15	0.0023
Phenylalanine + tyrosine	155.00^{b}	75.03^{c}	207.00^{a}	38	0.0001
Methionine+ cysteine	164.00^{a}	80.58^{c}	121.00^{b}	16	0.0001
Lowest chemical score (%)	52.80^{a}	18.14^{c}	39.20^{b}		0.0001
Limiting amino acid	Lysine	Leucine	Lysine		

Means with different letters in the same row are significantly different at ($p \leq 0.05$) according to LSD test

Table 4: Fatty acid composition of acorns produced by three *Quercus* L. species

	Q. aegilops	*Q. calliprinos*	*Q. infectoria*	*p-value*
Total saturated fatty acids %	20.29^{b}	21.42^{ab}	22.46^{a}	0.1233
Monounsaturated fatty acids (MUFA)%	56.24^{a}	54.92^{a}	56.43^{a}	0.3638
Polyunsaturated fatty acids (PUFA)%	23.57^{a}	23.71^{a}	21.15^{b}	0.0351
PUFA / MUFA (%)	41.91^{a}	43.17^{a}	37.48^{b}	0.0211
Total unsaturated fatty acids %	79.81^{a}	78.63^{a}	77.58^{a}	0.3918
Total unsaturated / total saturated ratio	3.93^{a}	3.67^{ab}	3.45^{b}	0.0535

Means with different letters in the same row are significantly different at ($p \leq 0.05$) according to LSD test

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 20 No. 5 September 2020 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 5: Mineral concentrations of acorns produced by three *Quercus* L. Species (µg/g; dry weight basis)

	Q. aegilops	*Q. calliprinos*	*Q. infectoria*	*p-value*
Potassium (K)	1137.00[b]	1135.01[b]	1222.50[a]	0.0001
Phosphorus (P)	85.50[b]	120.00[a]	55.50[c]	0.0001
Calcium (Ca)	60.00[a]	55.00[b]	40.00[c]	0.0001
Chlorine (Cl)	50.00[a]	33.00[b]	54.00[a]	0.0006
Sulfur (S)	9.00[c]	18.00[a]	11.85[b]	0.0001
Iron (Fe)	8.55[a]	7.65[a]	6.90[a]	0.2994
Manganese (Mn)	1.55[c]	2.40[b]	4.35[a]	0.0001
Zinc (Zn)	1.95[b]	3.45[a]	1.80[b]	0.0005
Copper (Cu)	1.65[b]	2.10[a]	1.65[b]	0.0086
Rubidium (Rb)	2.10[b]	1.80[b]	3.00[a]	0.0035
Rhenium (Re)	1.20[a]	0.90[b]	0.75[c]	0.0005
Bromine (Br)	0.15[b]	0.15[b]	0.45[a]	0.0001

Means with different letters in the same row are significantly different at ($p \leq 0.05$) according to LSD test

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